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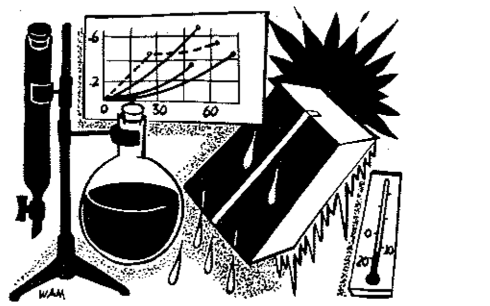

Starting a Program to Establish Standard Methods for Color Measurement of Processed Foods

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The Quartermaster Food and Container Institute recently initiated a color research program. The objectives are to study the relationship of color to quality and stability of foods and to develop practical specification standards and tests for control of color. The need for increased attention to color arises from Department of Defense and Department of the Army policy and guidance which require that all quality assurance provisions of subsistence specifications be based on objective end-product requirements. Recipe-type specifications which prescribe the use of ingredients of "good commercial grade" and processing according to "good commercial practice" are now becoming obsolete. The intent is to eliminate, is so far as possible, in-plant inspection by Government inspectors, and to rely instead on the vendor's testing of the end items. We attempt to control the quality of dehydrated potatoes, for example, by measuring color and reducing sugars in the finished product, rather than by prescribing temperatures for conditioning, cooking, and dehydrating.

The response of the consumer to color in foods is somewhat different from his response to color in other commodity groups. There is no standard color, for example, for a necktie and preferences vary widely. With regard to butter, eggs, mashed potatoes, etc., however, most consumers have a characteristic color in mind, and if a food varies markedly from this color, it is rejected. In other words the consumer is conditioned to expect a standard color for each of the foods he eats, and he associates food color with food quality almost instinctively. It is apparent, in view of these strongly established preferences, that color specifications must be correlated with consumer preferences.

Consumer preferences are not, however, the sole guide to color requirements for specification purposes. Color is also a measure of intrinsic qualities in foods; for example, the stage of maturity in fruits and vegetables, purity (as in spices), and chemical breakdown (as in products subject to browning).

The foregoing are background considerations with regard to color in food. In the foreground is the need to establish reliable instrumentation and techniques that can be used to pick out the color dimensions of concern in specification work. Research, therefore, will be directed toward determining the color values that can be written into specifications as end-product requirements to be met by the vendor. Since color measurement depends on the fact that colors can be matched by properly combining three primary lights, red, green, and blue, the relative amounts of each color that are required for a match—i.e., the tri-stimulus values of the color under study—are of primary concern.

Tri-stimulus Colorimetry

A fundamental approach to tri-stimulus colorimetry was considered essential to the development of meaningful color requirements. We started by studying the principles of colorimetry and their applications to food, and then discussed both the laboratory and practical aspects of the problem with those already experienced in this field. We are fortunate in having methods for measuring color at our disposal. There are, however, no standardized guides to the selection of methods or to the interpretation of results. What we do find is that neither visual methods nor instrumental methods are entirely reliable and reproducible. Also, that there is no single method which is applicable to all kinds of foods, or even to all situations pertaining to a single food. For example, a recent paper by Maier and Schiller (4) showed that the color of dates was characterized best by reflectance when the color was light, but by transmittancy of an aqueous-methanol extract when the color was dark.

Tri-stimulus colorimeters appear to be used most often in work reported in *Food Technology.* One large food processor in the Chicago area uses a tri-stimulus colorimeter for research on color and an abridged spectrophotometer with two narrow-band light sources for quality control. Another uses a tri-stimulus colorimeter for both research and for standardizing product quality among its plants. It is generally recognized that the performance of these tri-stimulus colorimeters and abridged spectrophotometers varies from instrument to instrument. The colorimeters are sometimes more conservatively and more accurately referred to as color-difference meters. They are most reliable for observing changes in color, as for example in following the course of a storage study; but they cannot always be relied upon for locating a color correctly in a color space. By comparing and standardizing the performance of these instruments, companies and regulatory agencies can use them success-

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fully for their own inspection and control of color. However, the tests for compliance with the Military specification requirements are to be conducted in the various vendors' laboratories which are not subject to control by a central authority. The lack of uniformity among the tri-stimulus colorimeters and abridged spectrophotometers rules against their application to our control problem.

Measurements by a tri-stimulus colorimeter can be duplicated in color chips which can be used for standards. Federal Standard No. 595 with 358 chips is an example. The reliability of such standards, however, depends upon the permanence of the colors and upon careful control of illuminating and viewing conditions under which they are used. For, unfortunately, terms of visual psychophysics such as tri-stimulus values, chromaticity coordinates, Hunter readings, Munsell notations, and others do not fully describe a color. Two colors can differ in spectral character and still have the same tri-stimulus values. They are color matches—so-called metameric matches—only under special lighting conditions. Colorimeters are therefore not so useful as their simplicity suggests. The spectrophotometer has been recognized as the basic instrument in the fundamental characterization of color by the Optical Society of America, the American Standards Association, the American Society for Testing Materials, the Technical Association of the Pulp and Paper Industry, and by others (2).

Physical Standards as an Approach to Color Control

A common approach to color control by Government agencies at the present time is the development of physical standards which have the same reflectance spectra as the foods. This is the approach being taken by the U.S.D.A. Agricultural Marketing Service at Washington and Beltsville, and also by the California Department of Agriculture. Standards in the form of pigmented plastic plates are used for visual comparison with the foods, but they also could be used for calibrating a colorimeter. It is true that the use of these chips requires judgment on the part of the observer. However, inasmuch as they have very nearly the same spectral characteristics as the food, their color is independent of the light source and the observer is concerned with only one variable—brightness. The match with the food in this case is said to be non-metameric. If the chip and food match, they will appear to have the same color, no matter what light is used for illumination and no matter what observer looks at them (3).

The QMFCIAF has also taken a step in the direction of developing such standards. Color standards for white potato granules were developed by the Eastern Regional Laboratory under contract with the Institute (5). These standards consist of mixtures of glass beads, powdered white glass, and three mineral pigments. The three standards, designated Good, Borderline, and Poor, have very nearly the same reflectance spectra as do potato granules which were judged to be representative of samples of good, borderline, and poor color. The three standards differ mainly in luminous reflectance, or lightness. In answer to some questions regarding these standards, Dr. B. A. Brice of the Eastern Regional Laboratory wrote as follows: "It was possible for us to make color standards for potato granules from inorganic, presumably light-fast ingredients because the separate potato cells could be approximated appearance-wise by commercially available glass beads. For dehydrated foods generally this simple solution to the problem of appearance or texture matching would probably be more difficult, and a properly textured molding of pigmented plastic might be the best solution."

One of the problems confronting us is the measurement of color uniformity when this property is intrinsically important. Dehydrated peas are an example. A single pea may have gradations in color ranging from near-white to dark green. There is no instrumental method for measuring this variability and specifying a desirable range in terms which any contractor or inspector can use for process control.

QMFCIAF Facilities for Color Work

It may be of interest to describe the Institute's facilities for color work. The laboratories were equipped with a Cary Model 14M recording spectrophotometer for the visible and ultraviolet regions of the spectrum, a Beckman Model DU spectrophotometer with reflectance attachment for visible and ultraviolet, a Perkin-Elmer Model 21 infrared spectrophotometer, and a Hunter Color and Color-Difference Meter. In addition, the Institute Library has the Munsell Book of Color and Charts, the Maerz and Paul Dictionary of Color, the Color Harmony Manual, and a number of the recognized reference books on color. During 1960, the Institute acquired the following additional equipment:

(a) A reflectance attachment for the Cary spectrophotometer. It has an integrating sphere, and visible, ultraviolet, and infrared light sources covering wave lengths from 275 millimicrons to 1.2 microns. The accessory illuminates the sample with diffuse, non-dispersed radiation and the reflected light is scanned by the monochromator.

(b) A "Color-Eye" tri-stimulus colorimeter and abridged spectrophotometer. It is equipped with tristimulus filters and 16 narrow-band filters spaced at approximately 20 millimicron intervals. It can be used both for reflectance and transmittancy measurements.

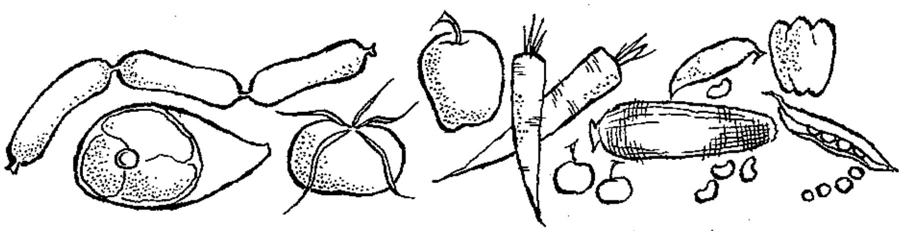
(c) The small aperture of the Cary reflectance attachment may be a disadvantage for spectral reflectance measurements on foods which are not entirely homogeneous in color and texture. In order to overcome this difficulty, a spinning device and optical cells were built in the Quartermaster Food and Container Institute Instrument Shop. These permit rotating the sample and effectively presenting an averaged surface to the instrument. The spinner can be used with either the Cary or the Color-Eye.

(d) A Macbeth color-matching booth equipped with light sources approximating north-sky daylight at 7500°K. and also horizon sunlight.

(e) U.S.D.A. pigmented-plastic color standards manufactured by Magnuson Engineers, Inc., and Federal Standard No. 595 color paper chips with C.I.E. designations.

Color as a Characteristic of Chemical Structure

Although the spectrophotometric curve provides a basis for the characterization of color, its relationship to psychophysical judgment is not readily apparent. No generalized statement can be made as



to what constitutes an important difference between two spectra. It depends on the wave-length at which the difference is observed and on the factors responsible for the difference. It is customary to transform the data into one of the established color-space systems and to set permissible tolerances subjectively.

Occasionally, changes in a restricted portion of a spectral curve have greater significance than the over-all change in color. For example, as lemons ripen, the greatest change occurs in the red portion of the spectrum. On the other hand, as corn matures, the apparent increases in yellow color results more from a decrease in blue reflectance than from an increase in yellow (1).

A better understanding of the chemistry involved in color changes is a logical forerunner to standardization and development of meaningful methods. Extraction and separation of pigments is usually necessary for their identification. What we learn about pigment concentration, however, may bear little relationship to appearance. It has been pointed out, for example, that two tomato juices of the same lycopene content but of different insoluble solids content present different appearances (6). Furthermore, the solubility of pigments is sometimes affected by processing. For example, the dark pigment which forms in blanched dates during storage is less soluble than that which forms in unblanched dates (4).

Much of the work which has been done on color in foods has emphasized physical measurement without regard to the chemistry involved. Color is as much an intrinsic characteristic of chemical structure as it is a property of light. As such, it is a manifestation of composition and physical state, in the same sense as are flavor, texture, stability, and functional performance.

Therefore, as we work toward improvement in color standardization and test methods, we propose to study the relationship of color to other properties of the foods. We consider it important to study cause and effect relationships between color changes and quality attributes quite distinct from esthetic eye appeal—such things as raw material quality and stability of the finished product.

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